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INVESTIGATION OF RECEIVERS DESIGNED FOR THE MEASUREMENT OF ULTRAVIOLET RADIATION IN THE UPPER ATMOSPHERE AND IN OUTER SPACE*

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SUMMARY

This paper presents the description of a vacuum diffraction ultraviolet monochromator for the investigation of spectral sensitivity of radiation receivers, such as photomultipliers, photon counters, ionization chambers.

A flow hydrogen lamp was used as the light source. Its spectrum is presented alongside with a table of wavelengths of certain lines. The registering circuit assures only the recording of the investigated radiation receiver's signal ratio to the signal of the reference photomultiplier with sodium salicylate-coated photocathode. The comparison of the photomultiplier with a vacuum thermocouple allows the realization of radiation receivers' absolute calibration

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When investigating the scattered ultraviolet radiation on altitude geophysical rockets, an earlier described apparatus was utilized [1, 2]. A nearly identical device was established on the space probe "ZOND-1" launched on 2 April 1964 [3]. Photon Geiger counters and ionization chambers filled with NO and windows made of LiF were utilized in all cases. In some of the cases an additional CaF_2 filter was installed ahead of the radiation receiver, cutting off the radiation with $\lambda < 1225$ A at normal temperature.

In the spectral region $\lambda < 2000$ A all the investigations of radiation receivers are carried out with the aid of a vacuum monochromator of normal incidence with a replica of a concave diffraction grating of 600 strokes/mm and 1 m curvature radius. The replica was covered with a layer of aluminum and magnesium fluoride, assuring a high reflection factor through λ 1000 A.

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* ISSLEDOVANIYE PRIYEMNIKOV PREDNAZNACHENNYKH DLYA IZMERENIYA UL'TRAFIOLETOVOGO IZLUCHENIYA V VERKHNEY ATMOSFERE ZEMLI I KOSMICHESKOM PROSTRANSTVE

The optical scheme of the monochromator of normal incidence (Johnson-Onako), utilized in the present device is described in detail in [4 – 6]. The dispersion of themonochromator is then practically constant in the range 1000 – 2000 A and is equal to 16.6 A/mm. The construction of the monochromator, projected and worked out at the Tartussk Astronomical Observatory, allowed to realize an independent exhaustion of the volume located past the outlet slot, which is extremely practical in case of frequent changeovers of investigated receievers. The time for photomultiplier counter or ionization chamber substitution or volume exhaustion does not then exceed 10 minutes.

The installtion scheme for the investigation of radiation receivers is shown in Fig.1. Beyond the monochromator's outlet slot there is disposed an inclined screen with slits passing in the direction perpendicular to that of the outlet slot. The screen is coated with sodium salicylate. Its glow, luminescencing under the action of ultraviolet radiation, is registered by the photomultiplier 3. Upon amplification the photomultiplier signal is fed to the automatic voltmeter 7. The other part of the light beam passes through the slits in the screen and is incident upon the investigated receiver 4. A dynamic electrometer B 2-5 was applied at investigation of ionization chambers for the registration of its signal, and in case of photon counters, a counting rate meter was used with a linear scale. Moreover, signals from both receivers (3 and 4) arrive into an analogue divider 11. The divider constitutes in itself a self-recording EPP-09 potentiometer in which the voltage of the standard battery is substituted by the signal of the reference photomultiplier 3.

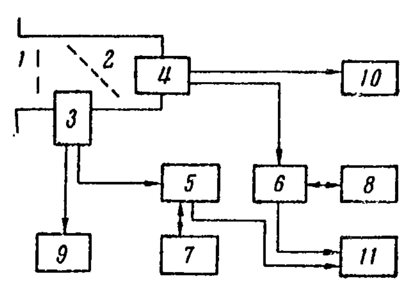

Fig.1. Principle of the calibration circuit of radiation receivers:

1) outlet slot of the monochromator; 2) slit screen; 3) reference photomultiplier; 4) radiation receiver investigated; 5), 6) amplifiers; 7) 8) control voltmeters; 9), 10) feed sources; 11) registering divider

Owing to the preceding the registered signal is proportional to the relative spectral sensitivity of the investigated radiation receiver (assuming, of course, the constancy of quantum yield of sodium salicylate [7, 8]). The fluctuation of source's brightness (flow hydrogen lamp) and the distribution of energy in its spectrum are not apparent in the registration. In case of an installation of a photomultiplier with a screen coated with sodium salicylate the registration has the shape of a straight line. This serves as a control of normal operation of the whole registering apparatus. The variation of lamp's current from 20 to 200 ma does not affect the readings of the device. The energy distribution in the spectrum of the source utilized by us is shown in Fig.2, and the wavelengths of the reference lines are compiled in Table 1 (see the following pages for both Fig.2 and Table 1).

Recording of the relative spectral sensitivity of photon counters and ionization chambers have been obtained with the aid of the above apparatues (see Fig.3).

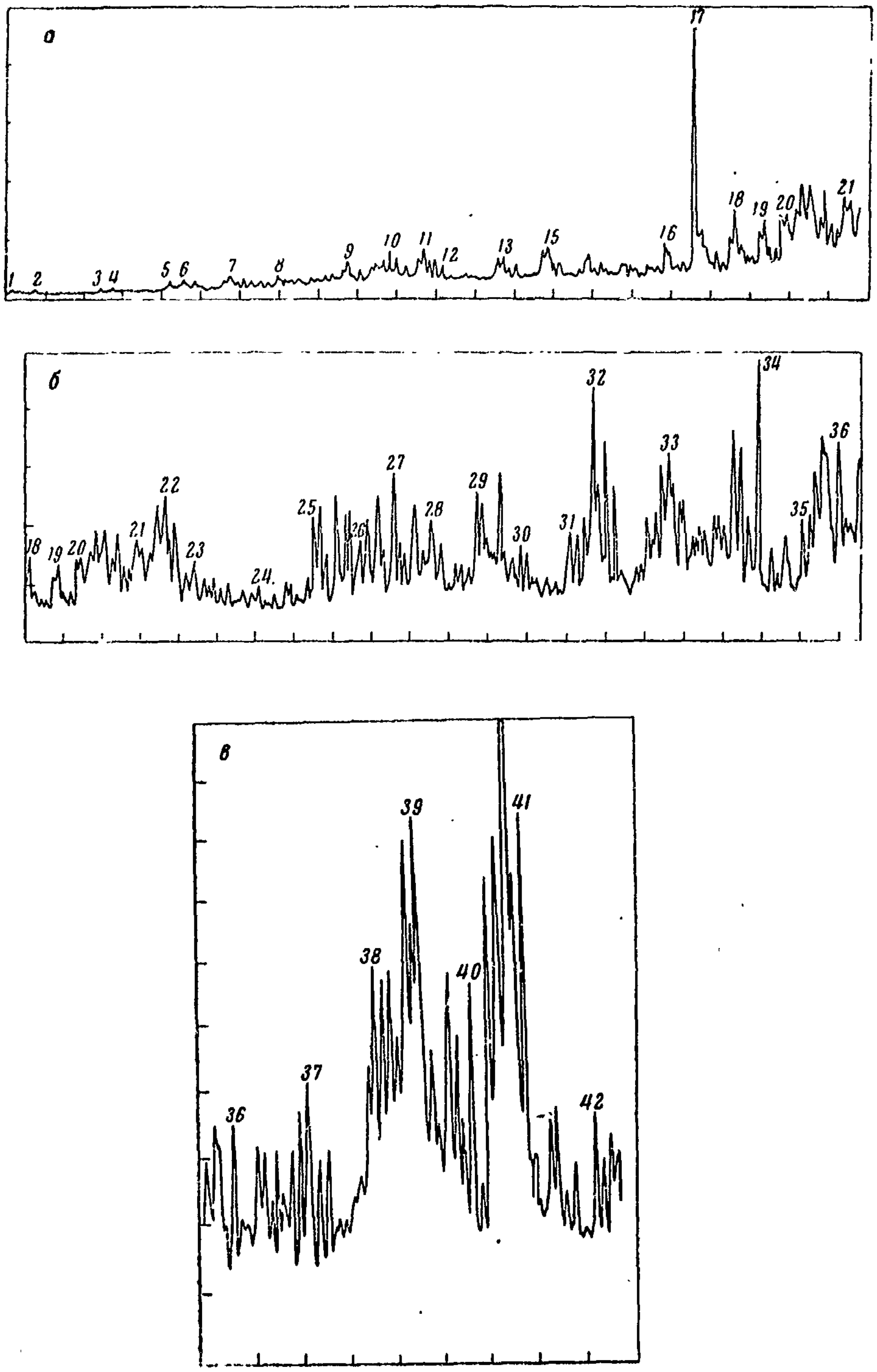

Fig.2. Spectrum of the hydrogen lamp registered by the reference photomultiplier

TABLE 1

WAGELENGTHS OF REFERENCE LINES OF MOLECULAR HYDROGEN'S ULTRAVIOLET SPECTRUM

№	λ, Å	№	λ, Å	№	λ, Å	№	λ, Å
1	967	12	1125	23	1291	33	1465
2	975	13	1146	24	1314	34	1498
3	991	14	1162	25	1334	35	1514
4	1004	15	1177	26	1351	36	1526
5	1026	16	1205	27	1364	37	1548
6	1031	17	1215,7	28	1379	38	1569
7	1046	18	1230	29	1395	39	1582
8	1064	19	1239	30	1411	40	1597
9	1090	20	1247	31	1429	41	1613
10	1105	21	1268	32	1438	42	1633
11	1117	22	1280				

The curves for chambers and counters filled with NO are analogous; however, there still are certain differences. Investigations of numerous counters show also that the depths of curve dips in various specimens of devices of identical type are not the same. But the position of the bands is constant on both the curves for chambers and for photon counters.

For comparison we plotted in Fig.3, the curve of relative spectral sensitivity of a counter with a window made of synthetic saphire and xylol filling

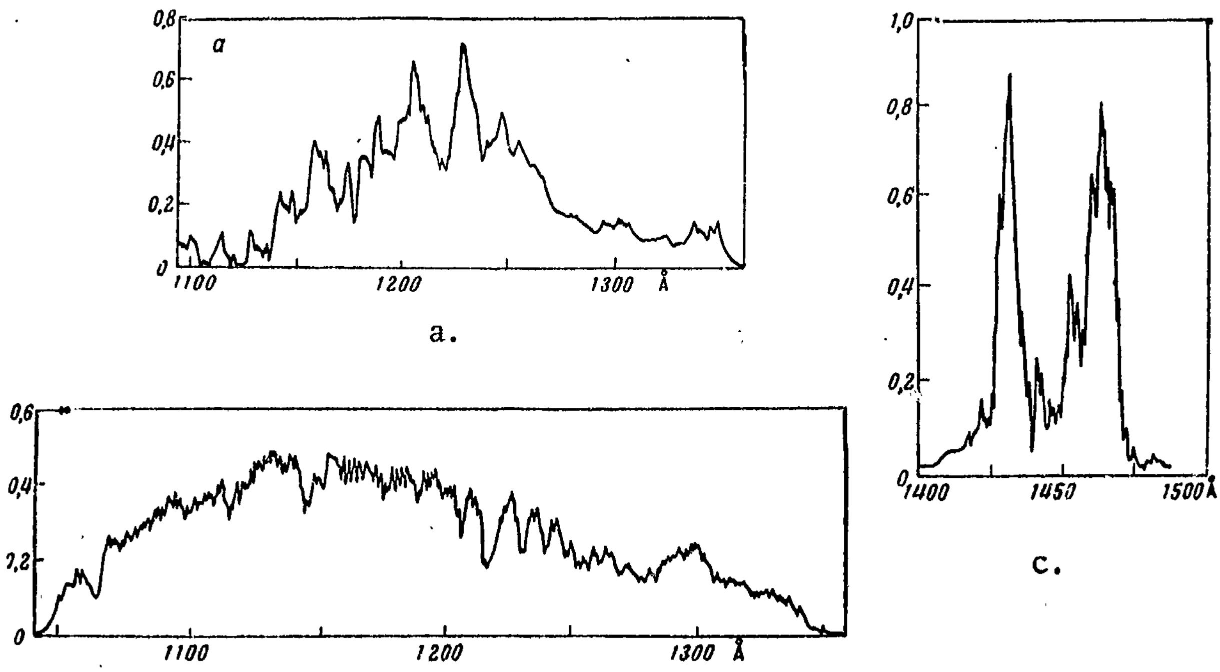

Fig.3. Curves of relative spectral sensitivity of :

a) a NO-filled ionization chamber; b) photon counters with NO filling and LiF window; c) photon counter with xylol filling and synthetic sapphire window.

For the determination of the absolute quantum effectiveness of the receivers, it is sufficient, in principle, to calibrate the reference photomultiplier making use of a nonselective radiation receiver. Unfortunately, however, the sensitivity of the vacuum thermocouple used by us was insufficient for the registration of the flux at monochromator output with the hydrogen lamp used. This is why the calibration procedure was chosen as follows.

The sensitivity of the photomultiplier with a screen of sodium salicylate to radiation with wavelength 2537 A was determined on the DMR-4 monochromator (a mercury lamp being used for the light source) by way of comparison with a vacuum thermocouple calibrated by the visible radiation at the Leningrad Polytechnical Institute in the name of Ul'yanov. It was subsequently admitted that the sensitivity of this photomultiplier is constant within a wide wavelength band and in a region where counters and ionization chambers are in operation, as well as at λ = 2537 A. Subsequent comparison of ionization chamber signals and also of those of counters with the readings of the photomultiplier allowed us to determine the absolute values of the quantum yield of these devices.

In the eight samples of ionization chambers measured by us, the quantum yield near λ 1216 A fluctuates from 5 to 20 percent. About the same values were obtained for the counters. These values differ from the theoretical one which may be computed by the Watanabe ratio of the effective ionization cross-section of NO to the total absorption cross-section ($\sim$0.83) and the leakage through windows made of lithium fluoride, which for our chambers was of the order of 40 percent. In other words the effectiveness must be situated within the 50 – 30 percent range, which is about twice as great as the values measured by us. The precision of our measurements, taking into account of the uncertainty of thermocouple calibration, constitutes 30 percent and can not be the cause of discrepancy. No such sensitivity variations of a multiplier with screen of sodium salicylate were observed with time, which might have been induced by quantum yield decrease of sodium salicylate. Nor was there noticed any water absorption effect by the window of the counter or of the chamber: at constant wavelength the reading is made 5 to 10 minutes after the beginning of exhaustion. However, we did not take into account the affect of quantum effectiveness variation of sodium salicylate with wavelength [10]. This is why it would be very important to repeat such measurements with a more sensitive thermcouple, which would allow us to eliminate the intermediate measurements with the photomultiplier having a screen of sodium salicylate.

***** THE END *****

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